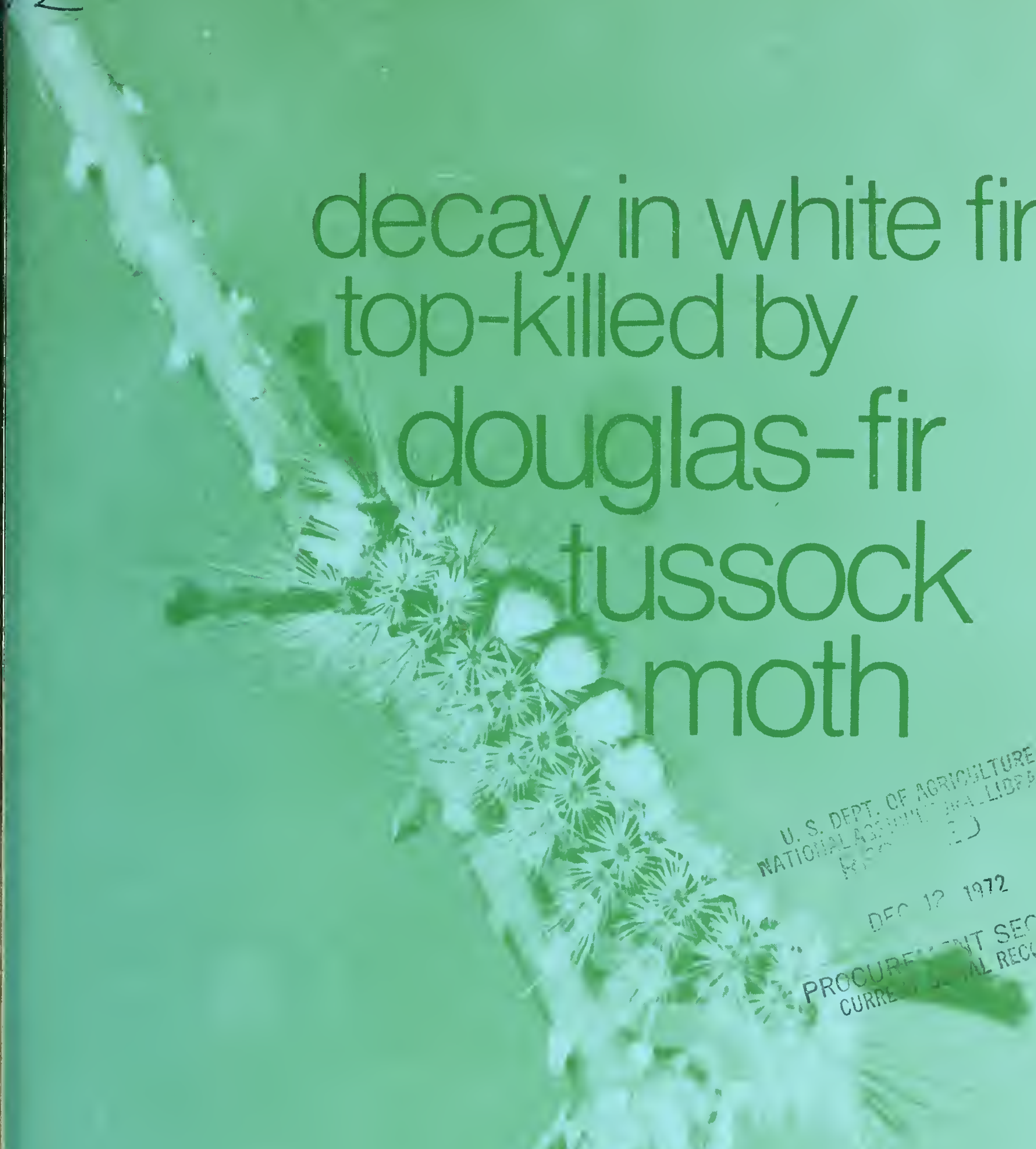
1972
usda forest service research paper pnw-133



decay in white fir top-killed by douglas-fir tussock moth

boyd e. wickman and
robert f. scharpf

pacific northwest
forest and range experiment station
forest service portland, oregon
u.s. department of agriculture

Boyd E. Wickman, *Principal Insect Ecologist*
Pacific Northwest Forest and Range Experiment Station
Corvallis, Oregon

and

Robert F. Scharpf, *Principal Research Pathologist*
Pacific Southwest Forest and Range Experiment Station
Berkeley, California

ABSTRACT

Stands heavily defoliated in 1936-37 by the Douglas-fir tussock moth, *Hemerocampa pseudotsugata* McD., at Mammoth Lakes, California, were studied to determine the incidence and extent of decay in top-damaged trees. This was done by dissecting the tops of trees felled during logging. Comparisons were made with white fir in a nearby logged area that was not defoliated during the old outbreak. Few decay organisms were isolated from trees top-killed by Douglas-fir tussock moth. However, old top damage and a condition known as wetwood were common in the infested area. Wetwood was found in 17 of 21 top-damaged trees in the infested area and in one of 50 trees in the uninfested area. We conclude, therefore, that in east-side Sierra Nevada white fir stands, the threat of defect is not economically serious in large trees that will be logged within 35-40 years after top damage.

Keywords: Wood decay, Douglas-fir tussock moth, *Hemerocampa pseudotsugata*, wood destroying fungi.

INTRODUCTION

One of the earliest recorded and studied outbreaks of Douglas-fir tussock moth, *Hemerocampa pseudotsugata* McD., on white fir (*Abies concolor* [Gord. & Glend.] Lindl.) occurred at Mammoth Lakes, California, from 1934 to 1938. A 5-acre plot was established there in 1937 to study the effects of defoliation. The tree damage resulting from this infestation and a later one on the Stanislaus National Forest in California consisted of mortality, growth loss, and top-kill (Wickman 1963). Heavy defoliation by the tussock moth can result in 12 percent of a stand being top-killed. The long-term effects of this damage have not been determined, but balsam firs top-killed by spruce budworm defoliation were found to have a high incidence of decay (Stillwell 1956). Decay fungi entering through dead tops of pole-sized white firs defoliated by tussock moth could result in timber losses from heart rot at the time of harvest.

A 1970 timber sale on the Mammoth Lakes District, which included part of the 1937 infestation and study area, offered an opportunity to determine if heart rots were a significant cause of defect in white fir trees 33 years after top-killing by the Douglas-fir tussock moth. Many of the pole-sized trees top-killed as a result of the severe defoliation are now of merchantable size and were included in the timber sale.

Our objectives were to investigate the pathological-entomological relationships of white fir top-killed by tussock moth. Specifically, we wanted to determine the presence and identity of wood destroying fungi, the extent of decay in trees with and without top-kill, and finally the amount of cull in top-killed trees as a result of decay.

METHODS

The study area is located on the Inyo National Forest on the east side of the Sierra Nevada several miles north of the Mammoth Lakes Ranger Station at about 8,000 feet elevation (fig. 1). The mixed conifer stand is composed mainly of white fir and Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.), but also contains scattered red fir (*Abies magnifica* A. Murr.) and lodgepole pine (*Pinus contorta* Dougl.). Many of the old-growth white fir were killed by secondary insects shortly after the infestation. In 1945 the area was logged for old-growth pine and any remaining old fir. The first relogging of the area began in spring of 1970. The logged trees sampled were 14 to 38 inches d.b.h. and 75 to 150 years old.

Figure 1.–Mammoth Lakes, California, Douglas-fir tussock moth plot area. Site of 1934-37 infestation (looking north from Sawmill Summit).

The 5-acre study plot was located in an old 1,000-acre infestation area, and

top-killed trees were measured on this plot. A nearby noninfested to lightly infested area[1/] included in the 1970 timber sale was used as a check. Wood samples were taken from trees with (1) spike tops, (2) bayonet, forked, or crooked tops (indicating an old buried leader), and (3) normal tops.

The trees on the old tussock moth plot were felled by the timber sale contract logger. His crews bucked the trees into 16-foot logs and also cut extra disks for us in the top portion. We followed the loggers and measured extent of decay and amount of cull by cutting a series of disks down the log from the point of initial top damage (fig. 2). We used Stillwell's (1956) method of recording data for later tabulation so we could make comparisons with his work on balsam fir top-killed by spruce budworm.

Figure 2.–Cutting samples from injured tops to determine the extent of decay.

Deformed tops were carefully examined to insure that the damage was a result of tussock moth defoliation. This was done by cutting disks immediately above, below, and at the point of leader damage and taking the ages at each cut. If the damage was due to defoliation or secondary insect attack, the upper disk had 27 to 32 annual rings; the lower disk, 29 to 34 annual rings; and the damaged disk contained the buried dead leader in the case of bayonet, forked, and crooked tops and had no more than 33 annual rings (fig. 3). Trees suffering top-kill before 1936 or after 1942 were not included in the decay determinations.

Data on the incidence of decay entering spike tops killed by fir engraver beetles, *Scolytus ventralis* (Lec.), were taken if the beetles had top-killed trees within 5 years after the tussock moth defoliation (fig. 4). Studies have shown that trees weakened by defoliation are susceptible to beetle damage for several years after defoliation stops (Wickman 1963). All felled trees with apparently undamaged tops were also checked (fig. 5).

Sample disks were put in plastic bags, taken to the laboratory and stored at 3^{o} C. All isolations were made within 1 week after collection.

Several wood chips were taken from within each of the sample disks by splitting them. They were surface sterilized in 0.1 percent sodium hypochlorite for 15 minutes, placed in petri dishes containing 2 percent malt agar and 100 p.p.m. streptomycin sulfate, and incubated at 20^{o} and 25^{o} C. for several weeks. During the period of incubation, fungi growing from the chips were hyphaltipped and grown in pure culture on 2 percent malt agar slants for identification. Decay organisms were identified by comparing the isolates with

---

[1/] *As determined from old insect survey maps and growth ring analysis.*

Figure 3.—A, Bayonet tops resulting from Douglas-fir tussock moth defoliation contain buried leaders.

Figure 3.—B, Forked tops resulting from Douglas-fir tussock moth defoliation contain buried leaders.

Figure 3.—C, Crooked tops resulting from Douglas-fir tussock moth defoliation contain buried leaders.

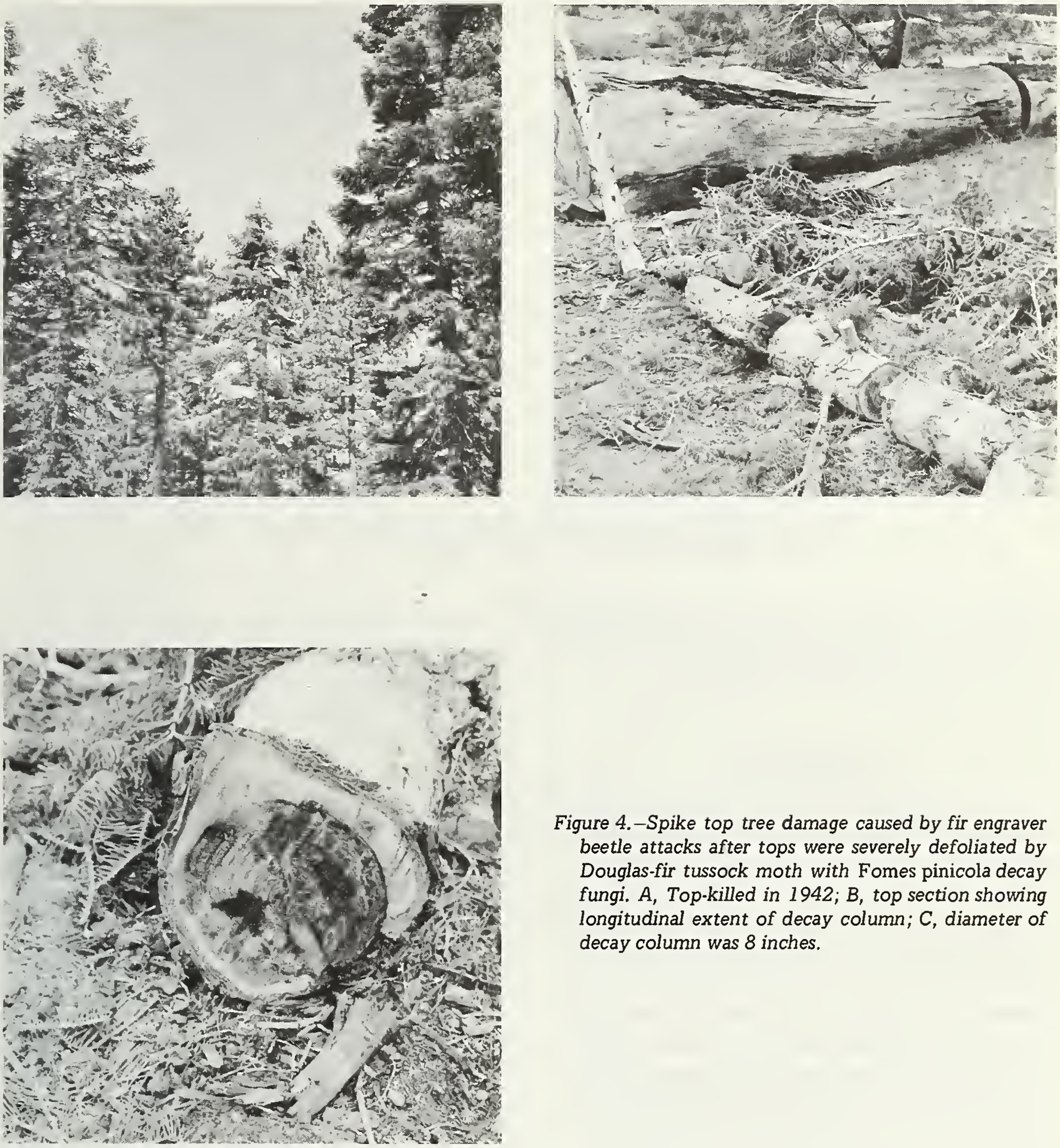


Figure 4.—Spike top tree damage caused by fir engraver beetle attacks after tops were severely defoliated by Douglas-fir tussock moth with Fomes pinicola *decay fungi. A, Top-killed in 1942; B, top section showing longitudinal extent of decay column; C, diameter of decay column was 8 inches.*

Figure 5.–Normal white fir tops, evidently only lightly defoliated during the tussock moth infestation, suffered no top-kill.

known pure culture of decay fungi in California and by using Nobles' (1948) methods and key to identify wood decay fungi.

RESULTS

Dissection and examination of trees with damage resulting from tussock moth defoliation failed to show the presence of typical decay. Field observations suggested that a high proportion of the trees with damaged tops had incipient decay in the living bole at the point of old top-kill. The presence of decay organisms was not confirmed in the laboratory, however. Only two of 21 top-damaged trees contained any decay fungi as indicated by laboratory isolation and identification (table 1). In both cases, *Fomes pinicola* , a common brown rot fungus, was present. In one tree sufficient rot was present to cull the top log. In the other tree no advanced decay was present, and the rot organism was isolated from wood chips taken at the point of top-kill.

The brown discoloration occurring in the central core of the living bole and resembling incipient decay was determined to be a commonly occurring discoloration of white fir wood known as "wetwood" (fig. 6). Wetwood in white fir is a physiological condition of unknown cause that

Figure 6.–Wetwood–dark stained area in the center of the cross section and to the right of the buried leader.

Table 1.--*Top damage as a result of Douglas-fir tussock moth defoliation and fir engraver attacks, 1936-42, at Mammoth Lakes, California*

Tree number	Diameter at stump (inches)		Total height (feet)	Length of top-kill or new leader (feet)	Dead leader			Longitudinal extent of wetwood below base of dead leader (feet)
	1970	1936			Diameter (inches)	Age (years)	Year of death	
DEAD SPIKE TOP (killed by fir engraver beetles)								
1	30	23	65	15	6	32	1938	16
2	18	14	60	20	8	34	1940	6
3	22	16	65	20	10	(1/)	1942	8 (decay)[2]
4	18	14	60	20	8	(1/)	1941	8
LIVE BAYONET, FORKED, OR CROOKED TOP (buried leader)								
5	24	9	60	30	2	10	1938	--
6	32	21	95	25	4	24	1936	1
7	35	29	112	12	3	6	1940	2
8	23	13	80	40	4	40	1939	8
9	22	10	60	30	4	42	1937	1
10	24	16	90	20	2	32	1938	3
11	22	14	85	20	1	5	1937	--
12	30	22	90	20	3	20	1940	3
13	14	8	40	20	2	29	1938	4 (decay)[3]
14	23	15	65	15	1	4	1936	--
15	19	13	75	15	1	8	1938	1
16	18	8	55	15	1.5	6	1938	1
17	18	12	65	15	4	33	1938	10
18	18	9	70	10	1.5	12	1938	1
19	30	22	105	20	4	38	1939	2
20	17	12	65	10	1	(1/)	1936	--
21	32	22	90	15	2	10	1937	1
NORMAL TOP								
22	30	20	105	--	--	--	--	--
23	24	20	95	--	--	--	--	--
24	30	24	115	--	--	--	--	--
25	15	10	70	--	--	--	--	--
26	22	14	90	--	--	--	--	--
27	37	29	115	--	--	--	--	--
28	32	26	105	--	--	--	--	--
29	18	12	70	--	--	--	--	--
30	22	14	75	--	--	--	--	--
31	16	12	60	--	--	--	--	--
32	24	16	90	--	--	--	--	--
33	33	27	110	--	--	--	--	--

1/ Could not be determined.

2/ 16 feet of cull.

3/ Extends 2 feet above base of dead leader.

appears in association with a particular species of bacterium (Wilcox and Schlink 1971). Wetwood, however, is most common in the lower bole of white firs and not usually found in the upper bole unless associated with injuries (Wilcox and Pong 1971).

Table 1 shows that of the trees with dead or damaged tops, 17 of 21 had wetwood in the living bole at the point of old top-kill. We also observed wetwood in six of 14 trees at a point 3 feet below the old injury. Three of 14 trees had wetwood in the merchantable top, and only one tree had wetwood extending into the new leader.

Of the white firs with no old damage or top-kill (this included 50 trees in the check area), only one of 57 trees had wetwood in the upper bole. In this particular case, old patch killing by fir engraver beetles was observed on the living top. There was also one cull top log, with defect due to decay, left by the loggers in the check area.

DISCUSSION

Stillwell (1956) found a higher incidence of decay in balsam fir top-killed as a result of spruce budworm defoliation than we found in white fir similarly damaged by tussock moth. He predicted that trees with tops killed back to a diameter greater than 0.5 inch and older than 5 years will eventually contain some decay. In our study, trees with tops killed up to 8 inches in diameter were free of decay. The only tree in our study with appreciable advanced decay was one with a 10-inch diameter dead top killed by fir engraver beetles.

In trees with buried leaders we found wetwood columns extending 1 to 10 feet in the tops, whereas Stillwell found decay columns 1 to 23 feet in the tops with many 8 to 10 feet in length. These discrepancies are most likely due to differences in insects, diseases, hosts, and local climate. For instance, Basham (1971) found no significant heart rot in eastern white pine (*Pinus strobus* L.), as a result of top-damage by the weevil (*Pissodes strobi* Peck). The weevil-caused top-damage occurred 16 to 20 years before the sample was taken and consisted of stem crooks containing buried leaders. Basham further predicted that it was unlikely that decay would form in these top-damaged trees.

Also, the climate of the Mammoth Lakes area is a factor that limits the occurrence and rate of decay. In this region of high elevation, short growing season, and low rainfall (about 28 inches annual precipitation, much of which is snow) the growth of decay fungi and development of heart rot are quite slow. On the other hand, in the coastal areas of northern California where temperature and moisture conditions are more favorable for decay fungi, broken and dead tops of white fir are considered a cull factor in marking timber (Kimmey 1950).

Another factor that may have limited the incidence of decay was the absence of heartwood in killed tops. Unpublished studies by Wilcox indicate that in a sample of white fir from the northern Sierra Nevada the average sapwood thickness was about 6 inches and the average number of annual rings in sapwood about 48. Thus, unless rather large tops are killed, decay fungi do not have direct access to heartwood and may be restricted in development by the sapwood.

The common occurrence of wetwood in association with dead tops is not fully understood. Perhaps dead tops provide entrance for the particular bacteria that bring about the wetwood condition, but wetwood is not confined to tops of merchantable size trees. We cut down three sapling-sized top-damaged trees (4, 8, and 10 inches d.b.h.), aged 55, 65, and 78 years, and found that two of the trees had their terminal shoots killed by the tussock moth. Both trees had extensive wetwood in the heart extending to the base of the tree. This condition has been found in almost all small trees top-damaged by the Douglas-fir tussock moth.

Canadians have also found an association of butt rot in balsam fir defoliated by spruce budworm, apparently caused by high rootlet mortality (Sterner 1970). Our examinations did not reveal a similar condition in white fir at Mammoth Lakes, but it might be a factor in other stands damaged by the Douglas-fir tussock moth.

The study revealed the importance of considering the insect-disease interrelationships in measuring growth impact and mortality in forest stands. Very often

the economic damage caused by one type of organism, whether pathogen or insect, can be traced to a condition caused by another type of organism. To understand the total losses from forest pests, this integrated insect-disease approach is often needed.

ACKNOWLEDGMENTS

This work could not have been conducted without the help of James Galaba, U. S. Forest Service, Mammoth Lakes District, who prepared the sale and arranged for our participation, and Mr. Bud Muller and his logging crew who felled study trees and cut extra sample disks.

LITERATURE CITED

Basham, J. T.
1971. Absence of decay development in two cases of top mortality in conifers. Bi-Mo. Res. Note, Can. Dep. Fish. & For. 27(3): 24.

Kimmey, J. W.
1950. Cull factors for forest-tree species in northwestern California. USDA Forest Serv. Calif. Forest & Range Exp. Stn., Forest Surv. Release No. 7, 30 p., illus.

Nobles, Mildred K.
1948. Studies in forest pathology. VI. Identification of cultures of wood rotting fungi. Can. J. Res. 26: 281-431, illus.

Sterner, T. E.
1970. Butt decay in balsam fir defoliated by the spruce budworm. Bi-Mo. Res. Note, Can. Dep. Fish. & For. 26(2): 17-18.

Stillwell, M. A.
1956. Pathological aspects of severe spruce budworm attack. Forest Sci. 2: 174-180.

Wickman, Boyd E.
1963. Mortality and growth reduction of white fir following defoliation by the Douglas-fir tussock moth. USDA Forest Serv. Res. Pap. PSW-7, 15 p., illus. Pac. Southwest Forest & Range Exp. Stn., Berkeley, Calif.

Wilcox, W. Wayne, and Clemens G. R. Schlink
1971. Absorptivity and pit structure as related to wetwood in white fir. Wood & Fiber 2(4): 373-379.

Wilcox, W. Wayne, and W. Y. Pong
1971. The effects of height, radial position, and wetwood on white fir wood properties. Wood & Fiber 3(1): 47-55.

GPO 985-996

Wickman, Boyd E., and Robert F. Scharpf
1972. Decay in white fir top-killed by Douglas-fir tussock moth. USDA Forest Serv. Res. Pap. PNW-133, 9 p., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

No decay resulting in cull occurred in trees top-killed by Douglas-fir tussock moth, and only one tree top-killed by fir engraver beetles contained decay which resulted in cull. However, a discoloration of the heartwood known as wetwood was common in top-damaged trees.

Keywords: Wood decay, Douglas-fir tussock moth, *Hemerocampa pseudotsugata*, wood destroying fungi.

Wickman, Boyd E., and Robert F. Scharpf
1972. Decay in white fir top-killed by Douglas-fir tussock moth. USDA Forest Serv. Res. Pap. PNW-133, 9 p., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

No decay resulting in cull occurred in trees top-killed by Douglas-fir tussock moth, and only one tree top-killed by fir engraver beetles contained decay which resulted in cull. However, a discoloration of the heartwood known as wetwood was common in top-damaged trees.

Keywords: Wood decay, Douglas-fir tussock moth, *Hemerocampa pseudotsugata*, wood destroying fungi.

Wickman, Boyd E., and Robert F. Scharpf
1972. Decay in white fir top-killed by Douglas-fir tussock moth. USDA Forest Serv. Res. Pap. PNW-133, 9 p., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

No decay resulting in cull occurred in trees top-killed by Douglas-fir tussock moth, and only one tree top-killed by fir engraver beetles contained decay which resulted in cull. However, a discoloration of the heartwood known as wetwood was common in top-damaged trees.

Keywords: Wood decay, Douglas-fir tussock moth, *Hemerocampa pseudotsugata*, wood destroying fungi.

Wickman, Boyd E., and Robert F. Scharpf
1972. Decay in white fir top-killed by Douglas-fir tussock moth. USDA Forest Serv. Res. Pap. PNW-133, 9 p., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

No decay resulting in cull occurred in trees top-killed by Douglas-fir tussock moth, and only one tree top-killed by fir engraver beetles contained decay which resulted in cull. However, a discoloration of the heartwood known as wetwood was common in top-damaged trees.

Keywords: Wood decay, Douglas-fir tussock moth, *Hemerocampa pseudotsugata*, wood destroying fungi.

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

Fairbanks, Alaska	Portland, Oregon
Juneau, Alaska	Olympia, Washington
Bend, Oregon	Seattle, Washington
Corvallis, Oregon	Wenatchee, Washington
La Grande, Oregon	

The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.